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# EFFECT OF SEAWATER ON PROPERTIES OF HDPE MATERIAL USED FOR FLOATING SOLAR APPLICATIONS

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***ABSTRACT***

***Solar Energy is one of the most renewable and ready sources of energy available in plenty and free on planet earth.Ground mounted solar PV system is used worldwide for installing the largesolar system. Due to the constraint of availability of space for ground-mounted solar system, some countries are utilising water bodies of sea & lakes etc. to install solar PV system. Due to low weight and excellent mechanical & chemical properties, structure made of plastic is used to install solar panel above it. It was found that High-Density Poly Ethylene (HDPE) plasticis widely used for making a structure to install a solar system. In order toanalyze the effect of sea water on properties of HDPE material, its mechanical properties havebeen evaluatedat different intervals till 2160 hours. The variation in the mechanical properties of HDPE material, like tensile strength, elongation at break, flexural strength, flexural modulus, impact resistance, hardness& water absorptionwere evaluated. It was observed that before & after 2160 hours of immersion in sea water, the tensile strength was increased from 24.62 MPa to 25.13MPa, % elongation at break was reduced from 75.81% to 52.81%. The flexural strength is initially increasedand after 768 hours, it is almost constant, however the flexural modulus is decreased. There is negligible change in properties of impact strength, hardness, melt flow rate, density after immersing the sample in sea water. It is established that the mechanical properties of HDPE material is not much affected, and hence it is suitable for making floats of structure, where solar panels are mounted.***

***KEYWORDS: Floating System, HDPE Material, Sea Water & Mechanical Properties***

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Original Article

## INTRODUCTION

The application of plastic material mainly commodity plastics (Polypropylene & Polyethylene) is increasing day by day due to their good mechanical properties, chemical resistance, light weight, durability, ease of manufacturing, low cost etc as compared with other materials. TheHigh Density Polyethylene (HDPE) material of Polyethylene group of material is second largest plastic material used worldwide [1]. The density of HDPE material is 0.940-0.965 g/cm$^3$ and also the mechanical properties are good, it is suitable for making floating solar panel structure [2]. Polyethylene is a stable polymer, where long chains of ethylene monomers are present and it cannot be easily degraded [3]. In many literature surveys, it is found that HDPE material is used for making floats, which is used as supporting platform to install solar panel on it, which can easily float over water bodies [4]. Degradation of supporting blocks under water bodies is accompanied by the change in the chemical composition of a polymer with time due to the effects of water, heat, sun light. HDPE floats can undergo degradation in different

ways depending on the environment. The polymers degrade in the outdoor environment, and the rate at which they vary mainly depends on their chemical structure. Polymer components normally fail either by bad engineering design or bad materials design or a combination of both [5]. Therefore, the composition of polymeric materials is important for determining its durability.

The HDPE material will be in continuous contact with sea water when the floating structure to install solar panel on it. The aim of this study is to evaluate the mechanical and chemical properties of HDPE material, which is used to make floats of structure to install solar panel, when used in sea water. Effect of sea water on properties of HDPE material was studied by many researchers. Sudhakar M. et al. (2007) studied bio fouling& degradation in sea water of High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP), and they observed that weight loss in LDPE was highest (2.5%) followed by HDPE (0.75%) & PP (0.5%) [6]. Guermazi N et al. (2008) studied the impact of aging in synthetic sea water on mechanical and structural properties of High Density Polyethylene (HDPE)immersed in synthetic sea water at 23 ± $3^0$C, $70^0$C and $90^0$C. After systematic study, they found that the mechanical properties viztensile strength, elastic modulus is decreased [7]. Artham T.et al. (2009) studied the biofouling & stability of four polymers Polycorbonate (PC), High Density Polyethyltne (HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP) in sea water, and they found that the biofouling and stability in terms of mechanical properties is lowest in PC followed by PP, HDPE & LDPE [8]. Muthukumar T et al. (2010) studied effect of marine water on three olefin material viz High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP) & they found that the decrease in mechanical properties is lowest in LDPE followed by HDPE & PP [9]. Sara L et al. (2015) studied Gravimatric, Mechanical & Chemical Charecterisation of Poly Vinyl Cholride (PVC), High Density Polyethyltne (HDPE), Polypropylene (PP) aged in acidic media & it is found that tensile strength of material is increased due to increase in crystalinity & decrease in elongation due to molecular change scission [10]. After reviewing the literature with respect to effect of sea water on properties of HDPE material, some of the authors havefound that HDPE material is losing its some of mechanical properties when it is in contact with sea water, but the analysis of other properties are not evident. The effect of the sea water on High Density Polyethylene (HDPE) is studied by evaluating the mechanical properties like Tensile Strength, Elongation, Flexural Strength, Flexural Modulus, Impact strength, Hardness, Density, Water Absorption, Melt Flow Rate before immersion in sea water and after immersion in laboratory developed sea water, for 2160 hours in different intervals.

## OBJECTIVE OF THE STUDY

HDPE plastic material is mainly used for floating solar installations at sea water. The HDPE material will be in continuously contact with sea water. The chemicals present in the sea water may affect the properties of HDPE material. In this experimental work, the effect of the sea water on HDPE floats was studied by evaluating the mechanical properties likeTensile Strength, Elongation, Flexural Strength, Flexural Modulus, Impact strength, Hardness, Density, Water Absorption, Melt Flow Rate, before and after immersion of HDPE samples in laboratory developed sea water at the intervals of 192, 384, 576, 768, 1536 & 2160 hours were studied and properties were evaluat

## EXPERIMENTAL

### Prepration of Sea Water at Laboratory

Sea water was prepared at laboratory, as per international standard ASTM D 1141 [11] for study of properties of HDPE material under influence ofsea water. The following composition as per ASTM D 1141 was used to prepare the sea

water in the laboratory as given in Table 1.

**Table 1: Composition of Sea Water**

| S. No. | Compound | Concentration, g/L |
|---|---|---|
| 1 | NaCl | 24.53 |
| 2 | $MgCl_2$ | 11.11 |
| 3 | $Na_2SO_4$ | 4.09 |
| 4 | $CaCl_2$ | 1.16 |
| 5 | KCl | 0.695 |
| 6 | $NaHCO_3$ | 0.201 |
| 7 | KBr | 0.101 |
| 8 | $H_3BO_3$ | 0.027 |
| 9 | $SrCl_2$ | 0.042 |
| 10 | NaF | 0.003 |

**Sample Prepration**

The test specimens are made from the High Density Polyethylene (HDPE) B6401 grade [12] of Haldia Petrochemicals Limited (HPL). The various mechanical propertiesofthis grade of material is measured and are given in Table 2.

**Table 2: Different Mechanical Properties of HDPE Material B6401**

| S. No. | Properties | Unit | Value |
|---|---|---|---|
| 1 | Tensile Strength | Mpa | 25 |
| 2 | Elongation at break | % | 76 |
| 3 | Flexural Strength | Mpa | 15 |
| 4 | Flexural Modulus | Mpa | 552 |
| 5 | Notched Izod impact strength | $KJ/m^2$ | 53 |
| 6 | Hardness | Shore D | 63 |
| 7 | Melt Flow Rate | Gm/10min | 0.41 |
| 8 | Water Absorption | % | - |
| 9 | Density | $g/cm^3$ | 0.957 |

The test specimen was prepared by Injection MouldingMachine ( JIT make, Philippines, 80 T capacity) for measuring different mechanical properties as per international standard (ASTM) shown in Table 3 [13].

**Table 3: Determination of Different Properties with their Test Methods**

| Test Properties | Test Method |
|---|---|
| Tensile Strength | ASTM D 638 |
| Elongation at break | ASTM D 638 |
| Flexural Strength | ASTM D 790 |
| Flexural Modulus | ASTM D 790 |
| Notched Izod impact strength | ASTM D 256 |
| Hardness | ASTM D 2240 |
| Melt Flow Rate | ASTM D 1238 |
| Water Absorption | ASTM D 570 |
| Density | ASTM D 792 |

The samples as per different ASTM standards are prepared as given in figure 1.

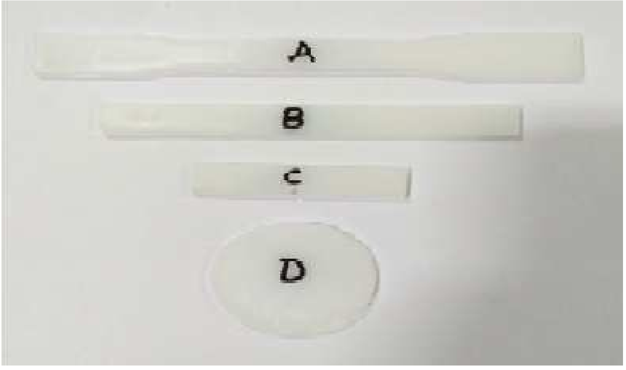


**Figure 1: Specimens for A) Tensile Properties B) Flexural Properties C) Izod Impact D) Density, MFR, Hardness, Water Absorption**

**Immersion of Test Specimen in Laboratory Developed Sea Water**

30 test specimens for carrying out tests as per 2.2 is immersed in two beakers filled with sea water, prepared in the laboratory as per 2.1 for 2160 hours (3monts). 5 Specimens for conducting tests as per table 3 are taken out at 192 hours (1 week), 384 hours (2 weeks), 576 hours (3 weeks), 768 hours (1 month), 1536 hours (2 months)& 2160 hours (3 months).

**Evaluation of Mechanical Properties**

**Tensile Strength &Elongation at Break**

The testing of immersed HDPE samples were done using Universal Testing Machine (Shimadzu make, Japan, 100 KN capacity). The tensile strength & elongation at break test was conducted according to ASTM D 638 [14] at a speed of 50 mm/min, gauge length of 100 mm at a temperature of 23± 2$^{o}$C and relative humidity of 50 ± 5%. The values of 5 specimens were taken, and the average values were reported.

**Flexual Strength& Flexural Modulus**

The testing HDPE samples were done using Universal Testing Machine (Shimadzu Make, Japan, 100 KN capacities). The flexural strength & flexural modulus test was conducted according to ASTM D 790 [15] at a strain of 1 % at a temperature of 23± 2$^{o}$C and relative humidity of 50 ± 5%. The values of 5 specimens were takenand the average values were reported.

**Impact Strength**

The Izod impact test (notched) was conducted in an Impact testing machine (Tinius Olsen, USA make, Model-IT 104). The izod impact test was conducted according to ASTM D 256 [16], using hammer energy of 2.7641 J at a temperature of 23± 2$^{o}$C and relative humidity of 50 ± 5%. The values of 5 specimens were taken and average values were reported.

**Hardness**

The hardness of samples before and after Immersing in Sea water were tested in a Shore D-Durometer(CASA Make). The hardness test was conducted according to ASTM D 2240 [17] at a temperature of 23± 2$^{o}$C and relative humidity of 50 ± 5%. The values of 5 specimens were taken and average values were reported.

### Melt Flow Rate

The Melt Flow Rate (MFR) was determined by Melt Flow Index tester of Ceast (Italy) make. The test was conducted according to ASTM D 1238 [18] at 190$^{o}$C at load of 2.16 Kg at a temperature of 23± 2$^{o}$C and relative humidity of 50 ± 5%. The values of 5 specimens were taken and average values were reported.

### Water Absorption

The water absorption test were determined by Metller Toledo balance, model- AB204-S/FACT. The test was conducted according to ASTM D 570 [19] at a temperature of 23± 2$^{o}$C and relative humidity of 50 ± 5%. The values of 5 specimens were taken and average values were reported.

### Density

The densities were determined by Metller Toledo balance, model- AB204-S/FACT fitted with density kit. The test was conducted according to ASTM D 792 [20] at a temperature of 23± 2 2oC and relative humidity of 50 ± 5%. The values of 5 specimens were takenand average values were reported.

## RESULTS AND DISCUSSIONS

### Analysis of Mechanical Properties

When plastics are immersed in sea water, its physical properties are affected. The original properties i.e. properties before immersion and properties after immersion in different intervals were measured & compared.

### Tensile Strength & Elongation at Break

The tensile strength of the material is slightly decreasedupto 384 hours, due to effect of absorption of water and reactions of chemicals present in the sea water. After 384 hours andupto 768 hours, the tensile strength is slightly increased due to deposition of chemicals, which increased the rigidity and stiffness and remains constant after 768 hours. The increase in tensile strength after 384 hours up to 768 hours may be because of stress transfer within polymers. Elongation is decreased up to 768 hours due to deposition of chemicals, which result in increase in stiffness after which, the variation is very nominal. The slight increase in elongation at break may be attributed to increase in ductility. Tensile property, mainly elongation at break value can be a good measure to monitor the ageing of polymers [21] .

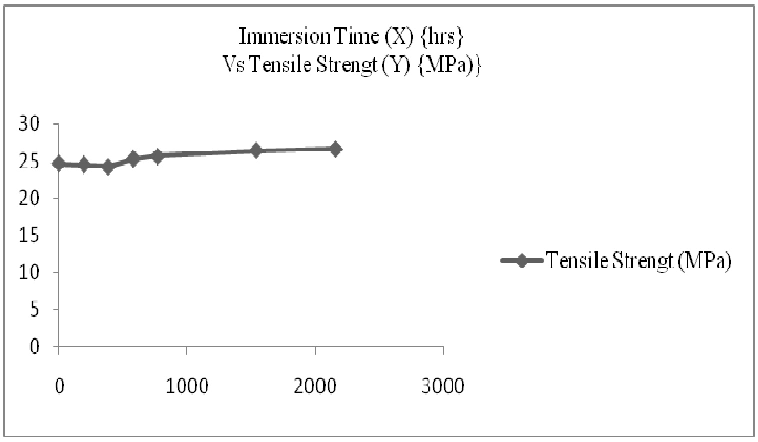


**Figure 2: The Variation of Tensile Strength w.r.t Immersion Duration**

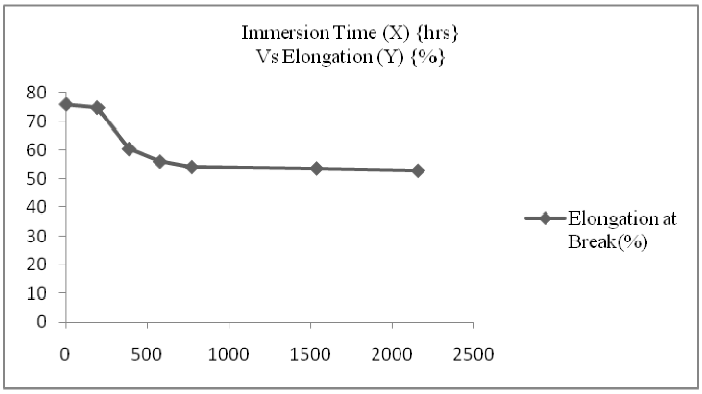


**Figure 3: The Variation of Elongation w.r.t Immersion Duration**

### Flexural Strength &Flexural Modulus

The Flexural Strength of the material is slightly increased up to 384 hours due to deposition of chemicals, which increased the rigidity and stiffness. After 384 hours and up to 768 hours, the Flexural Strength is slightly decreased due chemical reaction and remains constant after 768 hours. The flexural modulus is decreased gradually with time, due to absorption of water.

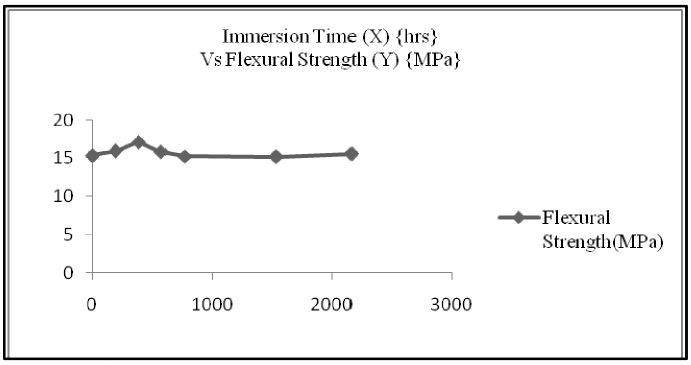


**Figure 4: The Variation of Flexural Strength w.r.t Immersion Duration**

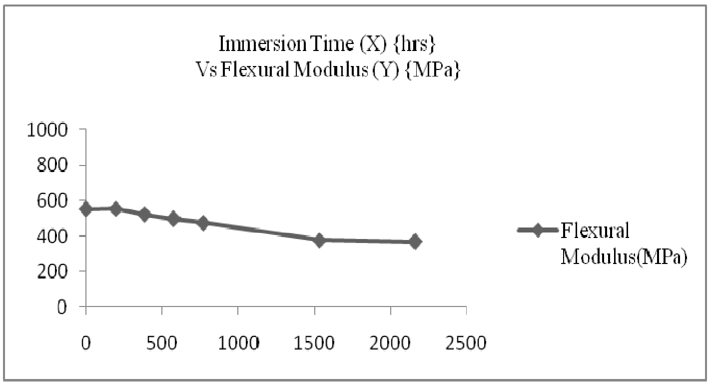


**Figure 5: The Variation of Flexural Modulus w.r.t Immersion Duration**

### Impact Strength

The impact strength of the material is slightly increased initially & after 768 hours, it remains almost constant. It shows that effect of sea water on impact strength is negligible. The slight increasing impact strength with the variation of immersion time may be because of high absorption energy during impact deformation.

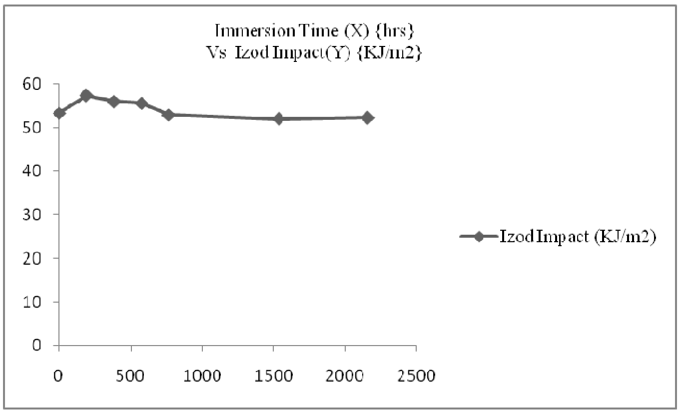


**Figure 6: The Variation of Izod Impact w.r.t Immersion Duration**

## Hardness

Hardness of the material is initially decreased then starts increasing and after 768 hours, the cross-linking reactions lead to increases in hardness [22], after which it is almost constant. It is also observable that the hardness increase very little with the increase of immersion time. This may be due to the class –linked density.

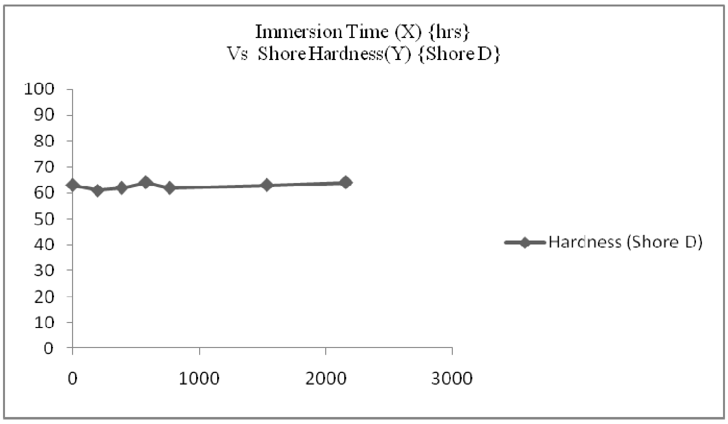


**Figure 7: The Variation of Hardness w.r.t Immersion Duration**

## Melt Flow Rate

Melt flow rate of material slightly is change negligibly. It shows that the material has not deteriorated with the immersion in sea water. The plot between melt flow rate v/s variations in immersion time clearly demonstrate that there is no change in melt flow rate i.e. there is no deterioration in melt flow rate. This finding may be attributed to unaltered viscosity of the materials.

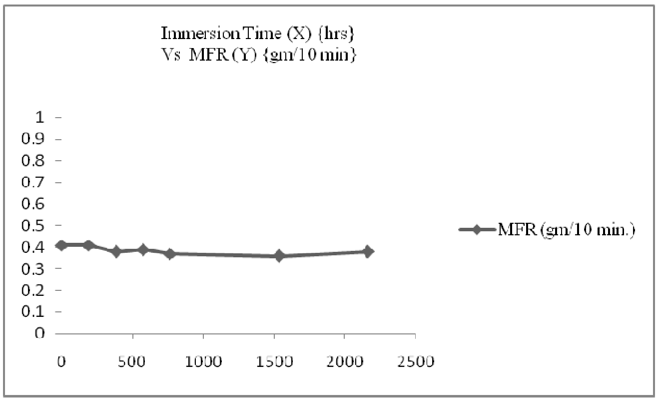


**Figure 8: The Variation of MFR w.r.t Immersion Duration**

**Water Absorption**

The water absorption till 192 hours was constant and after the material starts absorbing water till 576 hours, and again remains constant after 576 hours. The slight increase in water absorption within increase in immersion time may be because of water intake what up to 576 hours, after that there is no change in water absorption. This may be because of saturation of water intake achieved.

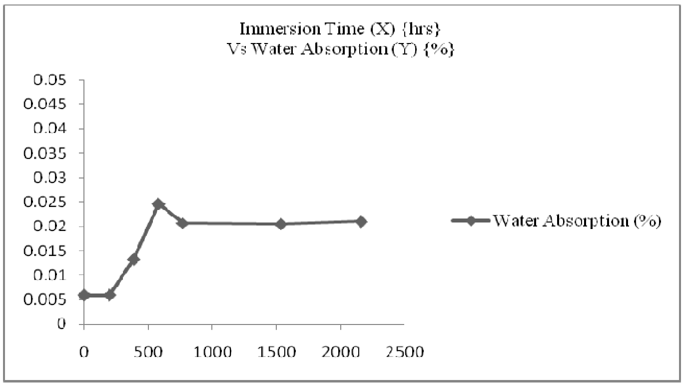


**Figure 9: The Variation of Water Absorption w.r.t Immersion Duration**

**Density**

Densityof material slightly is change negligibly. It shows that the material has not deteriorated with the immersion in ocean water. There is no change in density with the increase in immersion time because; volume section of the polymer is unchanged.

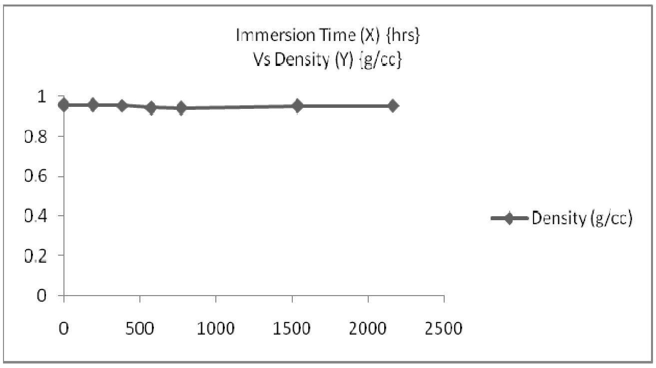


**Figure 10: The Variation of Density w.r.t Immersion Duration**

## CONCLUSIONS

The present research work highlights the effect on various properties of HDPE, when exposed to seawater at varied times.

- The mechanical properties results demonstrate that there is no appreciable change in tensile strength, and the maximum increase in in tensile strength has been achieved when the HDPE remains incontact with sea water at 768 hours.
- It has also been observed that there is appreciable reduction in elongation at break in allimmersion time in sea water. Initially there is little change in flexural strength up to 384 hours and after that it decreases.
- Mechanical properties clearly depict that there is no appreciable change in impact strength and hardness after 768 hours exposure of HDPE in sea water
- It is also obvious on the experiment that there is negligible change in density and melt flow rate.
- Thus, we can say that there is no effect of sea water at many interval times of HDPEmaterials up to 261 hours. It can be concluded that there is vast domain of application ofHDPE materials for making floats of the structure, where solar panels are mounted.

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